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THE USE OF SERUM AS A LATEX COAGULANT

BY

V. H. WENTWORTH

Summary

This paper describes the development of a method for using less formic acid as a coagulant in the preparation of smoked sheet.

It is shown that the serum remaining after a coagulation can be used to reduce the amount of fresh acid required for the next coagulation and that this can be repeated on several successive days. Details of the method were published in R.R.I. Circular No. 8 (November, 1939).

The limitations of the method are discussed, and the properties of the rubber obtained by the use of this method are compared with those of rubber prepared by the standard method of coagulation with formic acid.

The serious shortage of coagulants, particularly formic acid, which threatened after the outbreak of war, prompted an examination of possible methods of conserving supplies by a more economical use of the acid available (*R.R.I. Planters' Bulletin* No. 7 1939). One of the methods examined consisted of reducing the amount of fresh acid needed for a subsequent coagulation by utilising the serum remaining from a coagulation carried out with formic acid in the normal way. Normally this serum is thrown away.

The use of the residual acidity in serum as a means of coagulating latex is not by any means a new idea; de Vries (1920, 1; 1921) suggested its use for saving acetic acid, or for conserving water (by using it for diluting the acetic acid or for bringing the latex to a standard rubber content). Ultee (1918), Whitby (1918) and others also experimented on the same subject. These workers were interested primarily in the conservation of acetic acid which, since those experiments were made, has been almost entirely replaced as a coagulant (in normal times) by formic acid.

It is well known that latex will coagulate spontaneously, without any addition of acid, but the resulting coagulum is unsuitable for making into sheet; spontaneous coagulation also has a number of other disadvantages. For the manufacture of sheet, coagulation must take place within controlled limits of latex

dilution and of time in order to produce a coagulum having a texture suitable for machining into sheet of standard appearance. Likewise, any substitution of acid by serum must take into consideration its effects on the appearance of the sheet, from a market point of view, and on the inner properties of the rubber, from a manufacturer's standpoint.

The investigations described in this paper were designed to find out how far serum could replace formic acid whilst retaining the necessary texture of coagulum to enable it to be sheeted in the usual manner and to give a product equal to No. 1 quality R.S.S. They consist of a series of small-scale laboratory experiments followed by factory-scale coagulation trials using formulae developed from the small-scale laboratory experiments. The opportunity was also taken to observe certain changes which take place in serum when it is kept for short periods, and finally to compare the properties of the rubber prepared by using serum with those of rubber prepared by the usual acid-coagulation method.

Experimental

Dilution and Coagulation of Latex with Serum and with additional Acid

In estate practice, field latex, which has an initial dry rubber content of from 3—4 lb. per gallon, is usually "broken down"

TABLE I

Coagulations with Serum and with additional Acid

Experiment No.	Latex (d.r.c. 41.75%) (pints)	Water (pints)	Serum (*Titre 90.8) (pints)	Formic acid 1 per cent (fl. oz.)	Condition of		
					Coagulum	Serum	Dried Sheet
G 1/1	3	5	—	8	Satisfactory	Satisfactory	Satisfactory
G 1/2	3	—	5	—	„	Slightly milky	„
G 1/3	3	—	5	4	„	„	„
G 1/4	3	—	5	3	„	„	„
G 1/5	3	—	5	1	„	„	„

*Titre = ml. N—50 sodium hydroxide per 100 ml. of serum.

to a dry rubber content of 1½ lb. per gallon by diluting with water before adding the coagulant, in order to obtain a soft coagulum suitable for rolling into a sheet. In the first series of experiments the added water was replaced by serum, which served the double purpose of a diluent and a coagulant, and various quantities of formic acid were added as shown in Table I. Coagulation was in one gallon pans, the mixtures being allowed to stand overnight. The coagulum was sheeted next morning and then dried in hot air. The conditions of the serum after coagulation and of the sheets after drying were observed and are recorded in Table I.

In each case the coagulum was suitable for the manufacture of sheet although that prepared with serum was harder than the control (G 1/1) and showed some surface oxidation; the discoloration was less when the coagulum had been prepared with the higher amounts of formic acid. The dried sheets were free from bubbles.

Dilution and Coagulation of Latex with Water and Serum without additional Acid

The first series of experiments had shown that a satisfactory coagulum for the preparation of sheet could be obtained without the use of fresh acid, by using a certain quantity of serum to replace water used for the dilution of the latex in standard practice. It was next necessary to ascertain the smallest amount of serum

TABLE II

Coagulation with reduced amounts of Serum

Experiment No.	Latex (d.r.c. 41.71%) (pints)	Serum (Titre 81.2) (pints)	Water (pints)	Condition of		
				Coagulum	Serum	Dried Sheet
G 2/1 -	3	5	—	Satisfactory	Slightly milky	Satisfactory
G 2/2 -	3	4	1	„	„	Very bubbly
G 2/3 -	3	3	2	Poor	Milky	„
G 2/4 -	3	2	3	„	Very milky	„

that could be so used satisfactorily; a second series of experiments were made, using less serum whilst maintaining the same dilution by the addition of more water. As before, coagulations were

made in one gallon pans, using the quantities shown in Table II, and the conditions of serum, coagulum and the dried sheets were noted.

Table II indicates that if serum is used without additional acid for the coagulation of a 40 per cent d.r.c. latex, the proportions must be similar to those of Experiment G 2/1; it was also found that the serum remaining after coagulation of G 2/1 was unfit for further use in the same way because it produced a rough and bubbly sheet. Hence, serum alone could be used only once for the production of satisfactory sheet. This would be unsuitable for estate practice since uniform treatment of successive daily crops would not be possible.

Dilution and Coagulation of Latex with Water, Serum and Serum-acid Mixtures

It has been shown that satisfactory sheet could not be made by the repeated use of serum alone; another objection to serum is that it develops an unpleasant putrefactive smell if kept for several days. Also, the amount of latex which can be serum-coagulated is always less than that from which the serum has been obtained, owing to dilution by the latex, and the incomplete recovery of the serum. It is obvious, therefore, that for a repetition of the process, a proportion of formic acid must be used in conjunction with the serum, the latter supplying only a part of the acidity necessary for coagulation. The third series of experiments were therefore made to ascertain a suitable proportion of serum to formic acid. The quantities used in the pan coagulations are shown in Table III.

TABLE III

Partial Replacement of Acid by Serum

Experiment No.	Latex (d.r.c. 38%) (pints)	Water (pints)	Serum (Titre 81.2) (pints)	Formic acid 1% (fl. oz.)	Condition of		
					Coagulum	Serum	Dried Sheet
G 4/1	3.17	4.83	—	7½	Satisfactory	Satisfactory	Satisfactory
G 4/2	3.17	2.61	2.42	3¾	„	Slightly milky	A few bubbles
G 4/3	3.17	1.49	3.63	1⅞	Very porous	Milky	Very bubbly

As a result of these experiments and for other reasons already stated, it appeared that the replacement of about half the fresh acid by serum was the most that was likely to prove satisfactory in estate practice.

Changes in the Acidity of Serum during storage

A sample of serum was divided into four parts and treated with sugar and calcium chloride as shown in Table IV (see Appendix, page 144). Each of these materials has been used to hasten spontaneous coagulation of latex (de Vries 1920, 2); they were added to serum to ascertain whether a rapid increase in acidity would result before putrefaction set in, thereby enabling a smaller amount of either serum or formic acid to be used. Titrations were made at daily intervals up to seven days and the titres are recorded as ml. N/50 sodium hydroxide per 100 ml. of serum.

The changes observed in untreated serum (1/a) are typical of the effects of storage upon serum; Figure 1 (based on the data in Table IV) illustrates how the acidity falls to a minimum, regains its original value after four to five days and then steadily increases further. This additional acidity is of no practical value because of the accompanying putrefaction. The reasons for the observed changes in titre values can only be surmised but buffer action, microbiological consumption and hydrolysis are probably all involved.

The effects of the added substances in concentrations of 0.1 per cent were not particularly marked although there was an indication that cane sugar slightly delayed the drop in acidity. It was not considered desirable to use larger amounts.

Application of the use of Serum to Estate Practice

The small-scale experiments comprising "pan" coagulations indicated that approximately half the formic acid could be replaced by the acidity present in added serum, which served the double purpose of diluting and coagulating the latex. Experience has shown that observations made from small-scale experiments cannot always be repeated on a commercial scale. This and other aspects of the problem were investigated in the estate factory of the R.R.I. Experiment Station, where smoked sheet is in everyday production on a commercial scale. Coagulation in this factory is carried out either in 80 or 215-gallons coagulating tanks, using normally the following formula:—

Latex (diluted to 1½ lb./gal. d.r.c.)	—	200 gallons
Formic Acid	—	15 fluid ounces
Water (for dilution of acid)	—	10 gallons

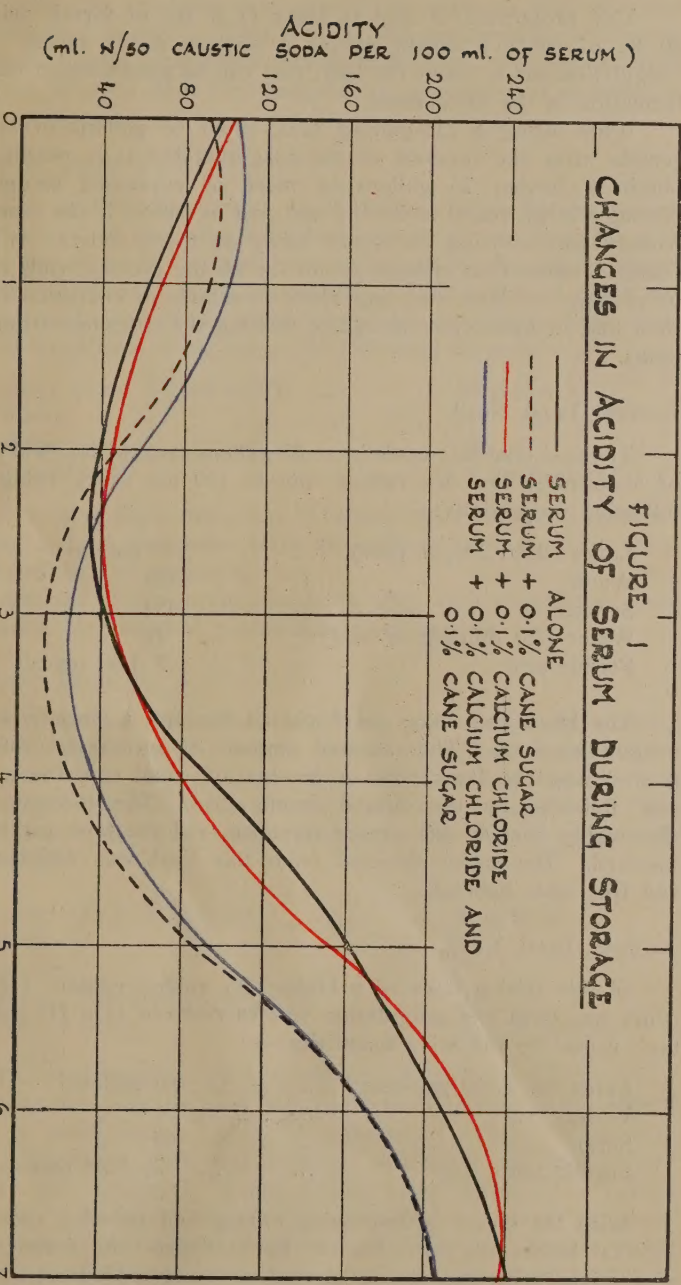
FIGURE 1
CHANGES IN ACIDITY OF SERUM DURING STORAGE
ACIDITY
(ml. N/50 CAUSTIC SODA PER 100 ml. OF SERUM)
0
40
80
120
160
200
240
0
1
2
3
4
5
6
7
PERIOD OF STORAGE (DAYS)
SERUM ALONE
SERUM + 0·1% CANE SUGAR
SERUM + 0·1% CALCIUM CHLORIDE
SERUM + 0·1% CALCIUM CHLORIDE AND 0·1% CANE SUGAR

This proportion of acid to latex (1 fl. oz. of formic acid to 20 lb. of rubber) usually leaves a slightly milky serum after coagulation and is about the least that can be used without bubble formation in the dried sheet.

When using a 215-gallons tank about 65 gallons of serum remain after the removal of the coagulum but it is possible to obtain a further 25 gallons or more of expressed serum by placing a large vessel under the first pair of rollers in the sheeting battery and omitting the water spray on those rollers. It was found however that enough serum for all the factory trials could be obtained without adopting special methods of collection other than that of lifting out instead of floating the coagulum from the tanks.

Factory Trial No. 1

The first trial was made in an 80-gallons tank with a field latex of abnormally low dry rubber content (30 per cent), using the following proportions:—

Latex (d.r.c. 30 per cent)	... ...	39 gallons
Water	... ...	19½ „
Serum	... ...	19½ „
Water (for dilution of acid)	... ...	1¾ „
Formic acid	... ...	3 fluid ounces

The latex and water were passed through a sieve into the coagulating tank. The required amount of serum was quickly poured into the latex from a number of small containers, and was followed by the diluted formic acid. The mixture was thoroughly stirred, the surface skimmed, and the tank partitions inserted. The sheet obtained from this trial was satisfactory and free from bubbles.

Factory Trial No. 2

In this trial a latex of a higher dry rubber content (38 per cent) was used and coagulation was carried out in a 215-gallons tank using the following quantities:—

Latex (d.r.c. 38 per cent)	... ...	80 gallons
Water	... ...	56 „
Serum	... ...	65 „
Formic acid	... ...	7¾ fluid ounces

With the object of improving mixing and reducing the time interval before the insertion of the partitions, the formic acid was mixed with the serum instead of being added separately,

otherwise the procedure was exactly the same as that described in Factory Trial No. 1. This method also gave satisfactory results —sheet of good appearance free from bubbles. Subsequent trials showed, however, that the rapid addition of serum was an unnecessary precaution.

Factory Trial No. 3

The preliminary results on a factory scale having proved satisfactory, it was next considered necessary to ascertain how often serum could be used repeatedly without having to revert to the sole use of fresh formic acid. Two series of eight and nine coagulations respectively, on consecutive days, were made in the 80-gallons tanks, using the following formula:—

Latex (d.r.c. 38 per cent)	... ...	30 gallons
Water	... ...	21 „
Serum	... ...	23 „
Formic acid	... ...	3 fluid ounces

In each of these two series of factory trials the sheets produced at the end of the series were as good in appearance as those produced at the beginning.

Samples of the serum remaining after each coagulation were set aside for chemical examination (see below)

Factory Trial No. 4

In this trial the method of mixing was modified by running the field latex into the serum instead of adding the serum to the latex as in the previous trials. This method has practical advantages but accentuates any tendency to pre-coagulation. The 80-gallons tank was again used and the following formula employed:

Latex (d.r.c. 38 per cent)	... ...	30 gallons
Water	... ...	19¼ „
Serum	... ...	23 „
Water (for dilution of acid)	... ...	1¾ „
Formic acid	... ...	3 fluid ounces

The serum and water were mixed together in the coagulating tank and into this the latex was run. After mixing-in the diluted acid the partitions were inserted in the usual manner. No trouble was experienced with this modified procedure and satisfactory rubber was produced. Some estates using serum as a partial coagulant found that, whereas they observed a tendency to obtain bubbly sheet when they added latex to the serum, better results were produced by following the previously described procedure

of adding the serum to the latex. To do this, however, a separate storage tank is needed for the serum, whereas if the latex is run into the serum, this can be kept in the coagulation tank in which it was produced.

Standardised procedure for use on Estates

As a result of these experiments a standard procedure was developed and described in R.R.I. Circular No. 8 (1939), using the following formula:—

Latex (diluted to 2¼ lb./gal. d.r.c.)	...	130 gallons
Serum	...	65 „ „
Water (for dilution of acid)	...	5 „ „
Formic acid	...	7½ fluid ounces

The standard procedure is as follows: Field latex in a bulking tank is diluted to a dry rubber content of 2¼ lb./gal. and then run into half its volume of serum in a coagulating tank, after which the diluted acid is stirred in and the normal procedure for sheet manufacture is then followed. This method was used repeatedly with success at the R.R.I. Experiment Station and on other estates.

The proportion of acid in the standard formula is slightly less than that used in the experiments. It was observed that the larger quantity of acid produced a coagulum which was harder than normal and more difficult to machine, resulting in sheets with thicker edges and a slower rate of drying.

Chemical examination of Serum from Factory Trials

The samples of serum collected from the series of extended tests in Factory Trial No. 3 were examined for acidity, after varying periods of storage, by titration with N/50 alkali. The results are shown in Table V.

In general the changes in titratable acidity of the serum had the same characteristics as those shown in Figure I (page 131) but the fluctuations were erratic from day to day. Possible causes of this were the chemical and bactericidal influence of sodium sulphite, which had been used in the field for the prevention of pre-coagulation of the latex and which was not subject to special control, the trials having been intentionally carried out under normal estate conditions.

TABLE V

Changes in Acidity on Storage of Serum from Factory Trials

Sample No.	Acidity (ml. N/50 sodium hydroxide per 100 ml. serum) after storage for (days)						
	0	1	2	3	4	5	6
Series							
A/1	86.8	76.8	—	86.0	122.0	176.0	232.8
/2	97.6	—	73.6	64.4	84.0	85.2	—
/3	—	54.8	50.4	49.2	71.6	73.2	—
/4	81.6	86.4	98.4	84.0	138.4	210.0	—
/5	50.0	42.8	40.0	83.6	143.6	—	—
/6	75.6	55.2	44.8	82.8	—	—	—
/7	65.6	65.6	64.8	—	120.0	—	—
/8	83.2	90.4	—	82.0	119.2	—	—
Series							
B/1	86.8	76.8	—	86.0	122.0	176.0	232.8
/2	98.4	—	74.8	57.6	65.6	89.6	—
/3	—	59.2	52.0	53.6	60.8	130.8	—
/4	76.4	71.2	69.6	68.4	102.4	145.6	—
/5	57.6	39.2	41.2	60.0	85.2	—	—
/6	100.8	79.2	54.0	55.6	—	—	—
/7	91.2	99.6	89.6	—	40.0	—	—
/8	84.4	81.2	—	78.8	192.4	—	—
/9	68.4	—	67.2	96.8	142.0	—	—

Examination of the Quality of Rubber prepared by Coagulation with Serum-Formic Acid

The evaluation of a material as a coagulant must take into consideration not only its effect on the appearance of the rubber but also whether it will affect its storage or manipulative qualities or the properties of the vulcanised product. The use of serum changes the total-solids content of the water phase of the diluted latex and introduces additional bacteria and enzymes.

In order to examine the properties of the rubber prepared by the repeated use of serum in the standard formula suggested for estate use, successive daily coagulations were carried out using serum and formic acid as a coagulant, and the resulting rubber was compared with controls prepared each day from a separate lot of the same latex. After the required amount of latex at 2¼ lb./gal. d.r.c. had been taken from the bulking tank

for coagulation with the serum-formic acid mixture, the latex remaining was diluted to 1½ lb./gal. d.r.c. and coagulated with formic acid in the normal manner.

The serum from the serum-formic acid series was retained each day after the removal of the coagulum, and used as the partial coagulant on the next day. The series of preparations (Tests No. 16-25) were made over a period of 11 days but no latex was available on the twelfth day, after Test No. 19 was made, and the serum for Test No. 20 thus had to be stored for *two* days before it was used. It was observed that the rubber from Test No. 21 was bubbly but that that from Test No. 22 on the following day was again free from bubbles. All the sheet was dried in four days in a Type A, R.R.I. Tunnel Smoke-house (Piddlesden 1938).

Another series of preparations were made extending over a period of five days only. The rubber from both series of preparations was tested but the results obtained from both series were similar and data are given only for the longer series. For conciseness in the following tables, rubber prepared by the normal method of coagulation with formic acid is described as the "Control rubber" and that by the use of the mixed coagulant of serum and a reduced quantity of formic acid is described as the "Serum-acid rubber."

Examination of the Serum from Tests 16 to 25

The total solids and acidity of the serum remaining each day, after the removal of the coagulum, are given in Table VI.

TABLE VI

Properties of Serum

Test No.	ACIDITY (Titre = ml. N/50 sodium hydroxide per 100 ml. serum) after coagulation with		Total Solids (percent) in Serum after coagulation with		Excess of total solids in the serum from serum-acid coagulation (by difference)
	Formic acid (Control)	Serum-acid mixture	Formic acid (Control)	Serum-acid mixture	
16	76.4	68.0	1.43	2.03	0.61
17	77.2	86.0	1.30	1.85	0.54
18	86.8	80.4	1.54	1.81	0.27
19	82.0	77.2	1.20	1.94	0.74
20	101.2	116.0	1.44	2.12	0.68
21	102.8	98.0	1.54	2.19	0.64
22	75.2	96.4	1.43	2.27	0.84
23	84.0	82.0	1.55	2.24	0.69
24	76.0	78.0	1.56	2.21	0.65
25	82.8	101.2	1.53	2.19	0.66
Average	82.4	88.4	1.45	2.09	0.63

Titre of original serum 75.6 ml.
Total solids in original serum 1.52 per cent

The repeated use of the standard procedure suggested for estates resulted in an increase of serum solids, but the daily process of dilution prevented the increase from becoming cumulative and the figures show a mean value of 0.63 per cent above the solids content of the control serum.

Acidity fluctuations were rather erratic but previous remarks concerning the use of anti-coagulant (sodium sulphite) are again applicable.

Properties of Raw Rubber

The principal difference shown by the serum from the serum-acid coagulation is its higher solids content and this, in conjunction with a probable increase in bacterial and enzyme activity might affect the resistance of the rubber to mould growth. Another characteristic of the raw rubber which might be changed is the nitrogen content, and this would probably affect the water-absorption capacity of the serum-acid rubber. These factors have been examined and it has been observed that no substantial changes

TABLE VII

Development of Mould

Test No.	First appearance of mould (days)		Surface covered with mould (days)	
	Control rubber	Serum-acid rubber	Control rubber	Serum-acid rubber
16	5	5	11	13
17	10	8	17	15
18	5	5	14	13
19	5	5	13	13
20	6	5	14	13
21	5	5	11	15
22	6	10	15	13
23	10	5	12	18
24	11	11	17	15
25	13	12	20	20
Average	8	7	14	15

were produced in any of these respects. It is however of interest to note that the serum-acid rubber displays the peculiarity of developing a dark colour during drying; it was not ascertained whether the darkening was due wholly to enzymic oxidation or to a greater absorption of smoke-bodies. Darkly smoked sheet is usually associated with high mould resistance.

Resistance to mould growth was determined by suspending samples of equal area, from the two series, over a 7 per cent solution of sodium chloride in a closed vessel at 90°F. and noting (a) when mould first appeared and (b) when almost the whole surface was covered (Table VII).

Nitrogen was determined by the standard Kjeldahl method using a mixed catalyst of selenium and copper sulphate.

Water absorption, which is often closely related to the nitrogen content of rubber, was determined by two methods: (a) by suspending a weighed thinly-sheeted sample in the water vapour over a saturated solution of potassium chloride at a temperature of 90°F. for eight days and re-weighing; and (b) by a modified Boggs and Blake (1926) test consisting of recording the increase in weight after immersing a standard-sized sample in water at 70°C. for 20 hours. The results are shown in Table VIII (see Appendix, page 144) and are graphed in Fig. 2.

The nitrogen content of the serum-acid rubber is lower than that of the corresponding control rubber although the serum used for coagulating the former had, as already shown, a higher total-solids content. This indicates a solubilising of the nitrogenous non-rubber constituents by bacteria or enzymes although it is probable that a part of the solubilised material remains in the rubber, together with other serum solids, and thereby contributes to the increased water absorption.

It is known that maturation of a coagulum causes decomposition of the serum substances with the formation of accelerators of vulcanisation (Eaton and Grantham 1915) and some of the effects observed are probably the result of the presence of increased amounts of these products—a conclusion which is supported by the vulcanisation results (see below).

The plasticity (D_{30} value) of the raw rubber was determined on the Williams plastometer by compressing a spherical pellet weighing 0.4 grm. for 30 minutes under a load of 5 kg. at a temperature of 100°C. The results are shown in Table IX (see Appendix, page 145), and are graphed in Fig. 3.

The serum-acid rubber is harder than the control rubber but the difference is unlikely to affect the manipulative properties of the rubber in the factory. Since harder rubber is usually associated with a higher serum-solids content it would appear that a proportion of the excess solids of the serum-acid mixture is retained in

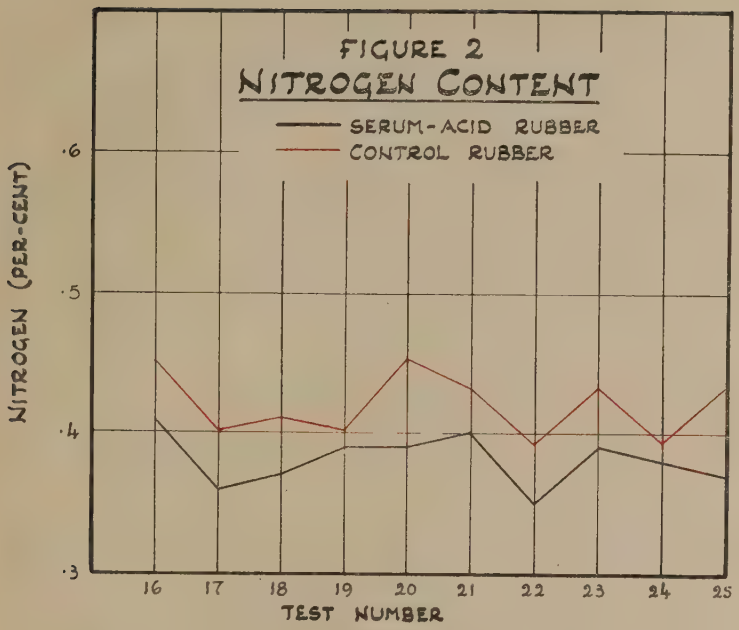
FIGURE 2
NITROGEN CONTENT
SERUM-ACID RUBBER
CONTROL RUBBER
NITROGEN (PER-CENT)
·6
·5
·4
·3
16
17
18
19
20
21
22
23
24
25
TEST NUMBER

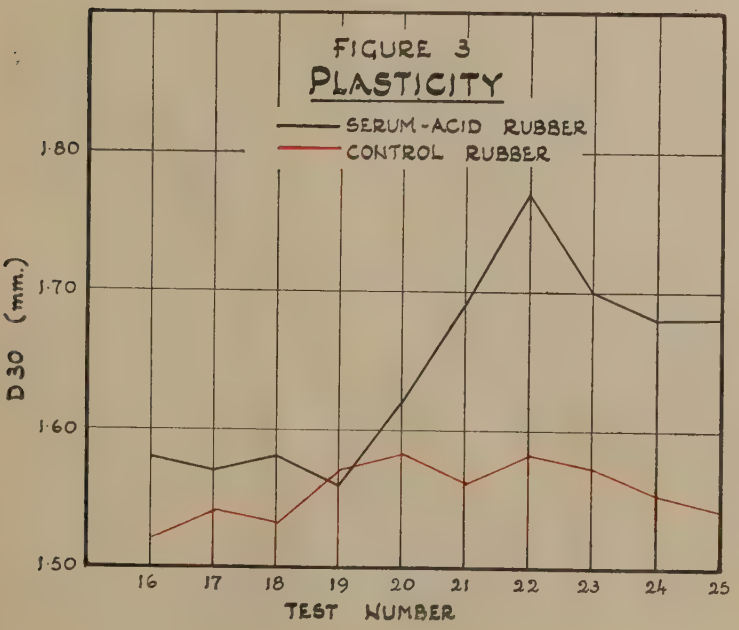
FIGURE 3
PLASTICITY
SERUM-ACID RUBBER
CONTROL RUBBER
D30 (mm.)
1·80
1·70
1·60
1·50
16
17
18
19
20
21
22
23
24
25
TEST NUMBER

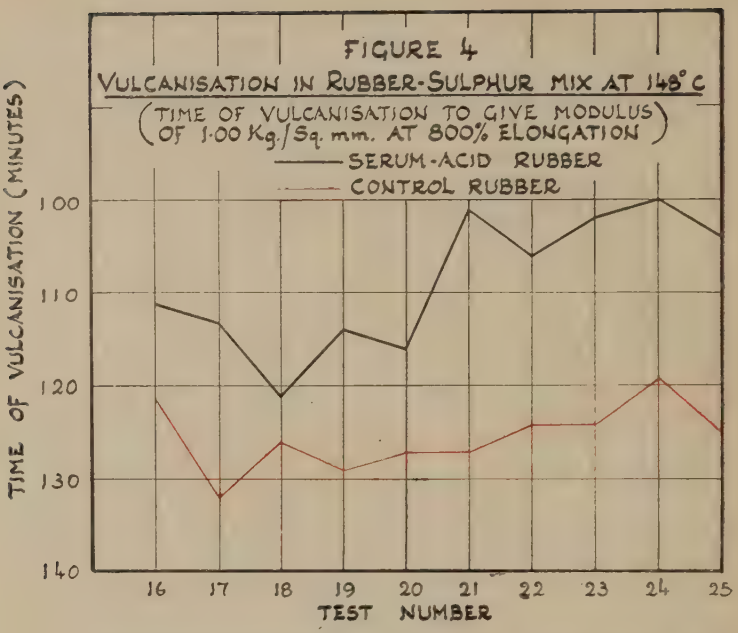
FIGURE 4
VULCANISATION IN RUBBER-SULPHUR MIX AT 148° C
(TIME OF VULCANISATION TO GIVE MODULUS OF 1·00 Kg./Sq. mm. AT 800% ELONGATION)
SERUM-ACID RUBBER
CONTROL RUBBER
TIME OF VULCANISATION (MINUTES)
100
110
120
130
140
16 17 18 19 20 21 22 23 24 25
TEST NUMBER

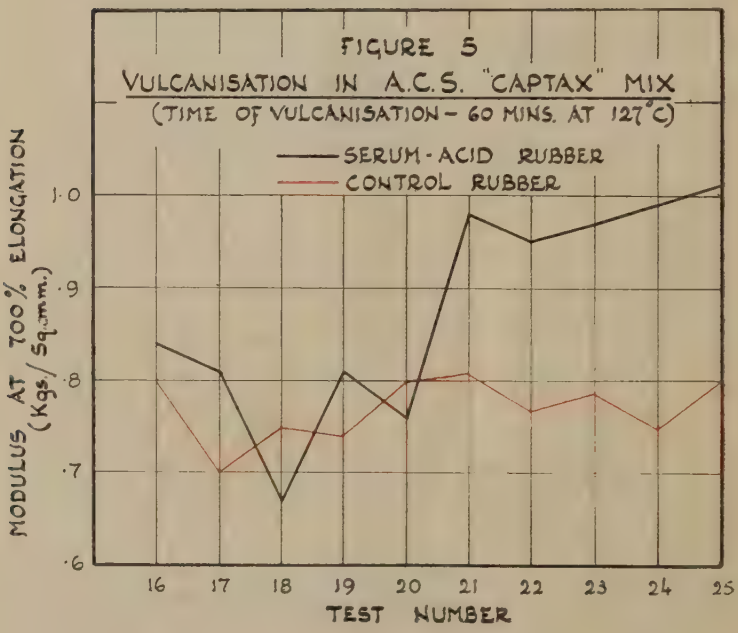
FIGURE 5
VULCANISATION IN A.C.S. "CAPTAX" MIX
(TIME OF VULCANISATION – 60 MINS. AT 127°C)
SERUM-ACID RUBBER
CONTROL RUBBER
MODULUS AT 700% ELONGATION (Kgs./Sq.mm.)
1·0
·9
·8
·7
·6
16 17 18 19 20 21 22 23 24 25
TEST NUMBER

the rubber, causing a slight hardening. The observation is in agreement with the slightly higher water-absorption capacity of the serum-acid rubber.

Vulcanisation Properties

The vulcanisation properties of the two series of rubbers were compared in two mixings (a) by a range of cures in a 100:10 rubber-sulphur mixing and (b) by means of a 60 minute cure at 127°C. in the "Captax" mixing suggested by the Crude Rubber Committee of the American Chemical Society (1939). The results of tests in the Schopper machine are shown in Tables X and XI (see Appendix, pages 145 and 146) and are graphed in Figures 4 and 5.

The results of tests in both the accelerator and rubber-sulphur mixings are in general agreement. Hastings and Rhodes (1939) have shown that a good correlation usually exists between the results obtained with these mixings. The data indicate that the use of serum increases the rate of vulcanisation and the average time-of-vulcanisation figures in Table X show this increase to have been approximately 13 per cent. Greater variability however also results; the curing times necessary to reach a modulus of 1 kg./sq. mm. at 800 per cent elongation in the rubber-sulphur mix show ranges of 21 and 13 minutes respectively for the serum-coagulated and control rubber. Any alteration in the methods of manufacture of smoked sheet which increases variability is undesirable and should be avoided if possible; the range of variation already existing in rubber from different sources is such that the use of serum would probably produce abnormal properties only in the faster-curing rubbers. The vulcanisation properties of slow-curing rubber would be brought nearer to the present average.

Use of Serum with other Acids

The work so far described has been concerned with formic acid and it has been shown that about one-half of the acid may be saved by replacing it with serum. Experiments made on similar lines with acetic and sulphuric acids indicated that the possible saving was somewhat less, being one-third for acetic acid and only about one-fifth for sulphuric acid. It was further observed that with sulphuric acid the limits of concentration necessary for satisfactory coagulation were very narrow.

A detailed study of the properties of rubber prepared by the use of serum in conjunction with acetic or sulphuric acid has not been made. In view however of the relatively small differences produced by the higher proportions of serum which can be used with formic acid it is anticipated that those produced by acetic or sulphuric acid serum would be smaller.

Discussion and General Recommendations

The method of coagulation which has been described and examined was devised to meet an emergency and to conserve supplies of acid. It has not been put forward as a method of reducing costs, since it is recognised that the risk of producing bubbly sheet is increased and a cut in the price of the rubber on that account would exceed the slight saving in acid cost.

The characteristics of latex depend upon such conditions as the strain of the trees, the nature of the soil on which the trees are grown, the weather conditions and the tapping systems in use and it may be found necessary to modify the standard formula which has been suggested. It is desirable that individual estates intending to use serum-acid coagulation should carry out a few experiments with higher proportions of fresh acid before making a 50 per cent substitution. However, ample evidence has been obtained from estates in widely differing localities to show that the method can be applied successfully.

If the latex is prone to pre-coagulation it has been found to be preferable not to run it into the serum but to add the serum to the latex.

On any day when there is no tapping it is best to discard the serum of the previous day's coagulation and to make a fresh start using acid alone. Estates have found that the risk of producing bubbly sheet increases with the number of repetitions of the process and, as a result of their experience, have fixed the number at which they find it desirable to end the series and start again. This procedure also has the advantage of keeping variability down to a low range, if the period selected is three or four days.

Summarising, the use of serum to assist coagulation produces a somewhat harder, dark-coloured and faster-curing sheet having a slightly reduced nitrogen content and increased water-absorption capacity but without an increased liability to mould growth. The method tends to increase the variability of smoked sheet and this, together with the possibility that the rubber may be subject to a cut in price on account of appearance, detracts from its use in cases other than of necessity. The shortcomings of the method are recognised but they are not serious and in abnormal times its possible value is considerable.

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APPENDIX

TABLE IV

Acidity changes in Serum on Storage (See page 130)

Ref. No.	Details of Serum			Acidity (Titre ml. N/50 NaOH per 100 ml. serum) after storage for (days)							
	Serum (Titre 90.8) (ml.)	Cane Sugar (gram)	Calcium Chloride (anhyd) (gram)	0	1	2	3	4	5	6	7
1/a	1000	—	—	90.8	50.8	35.2	40.8	—	162.4	210.0	240.4
1/b	1000	1	—	90.8	93.2	46.8	12.8	—	84.0	172.4	206.0
1/c	1000	—	1	98.0	64.0	39.2	28.8	—	146.0	216.8	230.0
1/d	1000	1	1	100.0	97.6	56.8	22.4	—	92.8	172.4	206.0

TABLE VIII

Nitrogen and Water Absorption (See page 138)

Test No.	Nitrogen (per cent)		Water absorption by vapour test (per cent)		Water absorption by immersion test (mg./sq. in)	
	Control rubber	Serum-acid rubber	Control rubber	Serum-acid rubber	Control rubber	Serum-acid rubber
16	0.45	0.41	0.78	0.77	28.6	23.8
17	0.40	0.36	0.70	0.78	23.2	25.5
18	0.41	0.37	0.69	0.76	20.0	23.8
19	0.40	0.39	0.67	0.69	21.5	25.0
20	0.45	0.39	0.89	0.81	21.9	29.4
21	0.43	0.40	0.80	0.91	30.1	33.8
22	0.39	0.35	0.68	0.85	23.4	32.2
23	0.43	0.39	0.71	0.82	24.3	29.3
24	0.39	0.38	0.75	0.89	27.6	24.3
25	0.43	0.37	0.75	0.86	23.7	23.4
Average	0.42	0.38	0.74	0.81	24.4	27.1

TABLE IX

Plasticity (See page 138)

Test No.	Thickness after compression (mm)	
	Control rubber	Serum-acid rubber
16 -	1.52	1.58
17 -	1.54	1.57
18 -	1.53	1.58
19 -	1.57	1.56
20 -	1.58	1.62
21 -	1.56	1.69
22 -	1.58	1.77
23 -	1.57	1.70
24	1.55	1.68
25 -	1.54	1.68
Average -	1.56	1.64

TABLE X

Vulcanisation in Rubber-sulphur mix at 148°C. (See page 140)

Test No.	Time of vulcanisation to give a Modulus of 1.00 kg./sq.mm. at 800 per cent elongation (minutes)	
	Control rubber	Serum-acid rubber
16 -	121	111
17 -	132 (highest)	113
18 -	126	121 (highest)
19 -	129	114
20 -	127	116
21 -	127	101
22 -	124	106
23 -	124	102
24 -	119 (lowest)	100 (lowest)
25 -	125	104
Mean -	125	109
Range between longest and shortest time of vulcanisation -	13	21

TABLE XI

Vulcanisation in the A.C.S. Captax Mixing for 60 mins. @ 127°C.

(See page 140)

Test No.	CONTROL RUBBER			SERUM-ACID RUBBER		
	Modulus at 700 per cent elongation (kg.)	Tensile Strength (kg./sq. mm.)	Elongation at break (per cent)	Modulus at 700 per cent elongation (kg.)	Tensile Strength (kg./sq. mm.)	Elongation at break (per cent)
16	0.80	1.67	864	0.84	1.65	847
17	0.70	1.71	895	0.81	1.76	869
18	0.75	1.48	857	0.67	1.74	905
19	0.74	1.65	876	0.81	1.82	879
20	0.80	1.74	875	0.76	1.76	876
21	0.81	1.69	865	0.98	1.84	842
22	0.77	1.56	852	0.95	1.78	835
23	0.79	1.67	864	0.97	1.92	852
24	0.75	1.60	862	0.99	1.80	829
25	0.80	1.63	855	1.01	1.78	824